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PREDICTION OF HC & NO_X EMISSIONS OF MAHUA OIL IN VCR DIESEL ENGINE

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ABSTRACT

Due to modernization and faster industrialization, results increase in use of vehicles and engines are increased, but facilitated with only limited energy sources. This situation leads to seek an alternative fuel for engines. Vegetable oils offer an advantage of comparable fuel properties with diesel. Due to considerable pressure on edible oils in India, short term performance of diesel engine was evaluated using Mahua oil as a fuel and its blends with diesel. It was found that Mahua oil could be easily substituted up to 20% in diesel without any significant difference in power output. and thermal efficiency. The performance of engine with Mahua oil blends improved with the increasing compression ratio from 12:1 to 18:1. Alternate fuels should be economically attractive in order to compete with currently used fossil fuels. In this work, biodiesel (Ethyl ester) was prepared from Mahua oil. Ethyl alcohol with potassium hydroxide as a catalyst was used for the transesterification process. The biodiesel was characterized by its physical and fuel properties including density, viscosity, flash point according to ASTM standards.

The emissions evaluation of a single cylinder four stroke VCR diesel engine has been done when fuelled with different blends of diesel and biodiesel made of Mahua oil. It was found that HC and NOx emissions of engine slightly decreases and with the increase in percentage of biodiesel.

KEYWORDS: Biodiesel, Transesterification, Mahua Oil, Compression Ratio, VCR Engine, Emissions

INTRODUCTION

Recent years high activities can be observed in the field of alternative fuels, due to supply of petroleum fuels strongly depends on a small number of oil exporting countries. Biodiesel and alcohol are being considered to be supplementary fuels to the petroleum fuels in India. These biofuels are being looked to provide employment generation to rural people through plantation of vegetable oils. Biodiesels are derived from edible oils and non edible oils such as Jatropha, Pongamia, Mahua, Cottonseed, Soy bean, Neem, Sunflower, Rapeseed, Palm etc. Cotton Seed Oil (CSO) was the first commercial cooking oil in many countries but it has progressively lost its market to other vegetable oils that have larger production and less cost. With the active researches on biodiesel production from vegetable oils, there is a promising prospective for the cottonseed oil as a feedstock for biodiesel production, which may enhance the viability of the cottonseed industry. Mahua oil is obtained from the seeds of Madhuca Indica, a deciduous tree which can grow in semi-arid, tropical and sub-tropical areas. It grows even on rocky, sandy, dry shallow soils and tolerates water logging conditions.Direct use of vegetable oils or animal fats as fuel can cause numerous engine problems like poor fuel atomization, incomplete combustion and carbon deposition formation, engine fouling and lubrication oil contamination, which is due to higher viscosity. Hence the viscosity of vegetable oils can be reduced by several methods which include blending of oils, micro emulsification, cracking / pyrolysis and transesterification. Among this transesterification is widely used for industrial biodiesel production.

Mahua Seeds

Mahua seeds contain about 40% pale yellow semi-solid fat. The seed oil is commercially known as 'Mahua Butter'. The oil content of the seed varies from 33 to 43% of the weight of the kernel and Mahua oil is by far the most important of the tree seed oils. Fresh Mahua oil from properly stored seeds is yellow in color with an unpleasant taste.

Reasons for Choosing Mahua Oil as an Alternate Fuel

Wood of Mahua tree is hard and heavy, good fuel wood, calorific value of sapwood is 4890-4978Kcal/kg and heart wood 5005-5224Kcal/kg. Flowers yield alcohol which can be used as engine fuel. Mahua flower yields alcohol 340 litre/tone flower. Fruit pulp may also be used for alcohol production. Seed cake with cattle dung yields biogas and fertilizers. Bio diesel from Mahua seed is important because most of the states of India is found abundantly. Mahua seed contain 30-40 percent fatty oil called Mahua oil. The Mahua tree starts bearing seeds from seventh year of planting. Mahua seed oil is a common ingredient of hydrogenated fat in India. It is obtained from the seed kernels and is a pale yellow, semi-solid fat at room temperature. It is also used in the manufacture of various products such as soap and glycerine. The properties of the Mahua Oil were found to be within the biodiesel limits of various countries. Hence the Mahua Oil can be used as a substitute for diesel, for sustainable development of rural areas and as a renewable fuel.

Table 1: Composition of Mahua Oil

Palmitic Acid	24.5%
Stearic Acid	22.7%
Oleic Acid	37.0%
Lionolic Acid	14.3%
Unsaponifiable matter	1.5%

Table 2: Fuel Properties of Mahua Oil

Property	Diesel	Esterified Mahua Oil
Kinematic Viscocity(cst)	3.8	2
Flash Point (^{0}C)	72	75
Fire Point (^{0}C)	75	78
Density (kg/m^3)	830	901
Calorific Value (kJ/kg)	42500	38900

LITERATURE REVIEW

[1]The cold point is higher, indicating problems of thickening or even freezing at low ambient temperatures. It is evident that vegetable oils are much less volatile than diesel. This makes their slow evaporation when injected into the engine. Vegetable oils have cetane numbers of about 35 to 50 depending on their composition. [2] Lehman et al. obtained high ester conversion with a 6:1 M ratio of methanol to vegetable oil. In the process of peanut oil esterification, the 6:1 M ratio liberated significantly more glycerol than the 3:1 M ratio. These investigators also found that glycerol yields increased from 77% to 95% as the sodium hydroxide catalyst increased from 0.2% to 0.8% at the 6:1 M ratio. Fatty ester is the major product, and glycerol is the by-product.[3].Ramesh et al. investigated the performance of a glow plug-assisted hot surface ignition engine using methyl ester of rice bran oil as fuel. Normal and mnemonic crown pistons were used for their tests.[4] Panwar et al. conducted an experiment in single-cylinder variable compression ratio diesel engine at different loads. The engine performance for castor methyl ester was investigated. The lower blends of biodiesel increased break thermal efficiency and reduced fuel consumption. [5] Jindal et al. studied about the comparison of performance and emission characteristics for different compression ratios along with injection pressure, and the best possible combination for operating engine with Jatropha methyl ester has been found. [6] Monyem and Van Gerpen conducted experiments to

characterize the effect of oxidized biodiesel on engine performance and emissions. They used methyl soyate for testing a John Deere turbocharged direct-injection diesel engine.[7] Ishikawa et al. performed early injection PCCI on an engine and a vehicle at low load operating conditions using high EGR rates.[8] Murata et al. reported a 60% reduction in both NOx and PM with a very minute increase in fuel consumption in a single-cylinder engine. They used early fuel injection with high EGR rates and reduced ECR by intake valve closing (IVC) modulation. The model was validated against different operating points using engine data from Cummins. In addition, the model was also validated with data from a second engine of similar make at Purdue University's Herrick Laboratories. This model will be used here for the simulation study. After reviewing the listed papers Mahua oil is also most prominent for improving emission characteristics of diesel engine.

EXPERIMENTATION

Preparation of Biodiesel

Bio-diesel is prepared to reduce the viscosity of oil and ready usage in diesel engine for emissions evaluation. The problems with substituting triglycerides for diesel fuels are mostly associated with their high viscosities, low volatilities and polyunsaturated character. These can be changed in at least four ways: Pyrolysis, Micro-emulsification, Dilution and Trans-esterification

Trans- Esterification

The most common way of producing biodiesel is the transesterification of vegetable oils and animal fats [6, 8-11]. Oil or fat reacts with alcohol (methanol or ethanol). This reaction is called transesterification. The reaction requires heat and a strong catalyst (alkalis, acids, or enzymes) to achieve complete conversion of the vegetable oil into the separated esters and glycerin.

Chemistry of Trans-Esterification Process

CH_2COOR_1 CH_2OH R_1COOR

| | |

$CHCOOR_2$ + 3ROH ←--------→ CHOH + R_1COOR

| | |

CH_2COOR_3 CH_2OH R_1COOR

(Triglyceride) (Alcohol) (Glycerin) (Biodiesel)

Transesterification Mixture

The following Proportions used for the preparation of Bio-diesel: Mahua oil (1 litre), Methanol (200 ml) and Lye (KOH or NaOH) (5gms).

Manufacturing Process

Mahua oil is filtered to remove solid particles.Mahua oil is then heated upto 100˚C to remove moisture content.Exact quantity of Potassium Hydroxide(KOH) also known as Lye, is then thoroughly mixed in methanol till it dissolves completely to get potassium methoxide.Now this mixture is stirred for about 50-60 minutes and simultaneously heated below the flash point temperature. It is then allowed to settle for 24 hours.Bio-diesel will be formed at the top of the container and all the high denser particles will be formed as the by-product (glycerine) is removed from bottom.Bio-diesel fraction is then washed and dried, and then checked for quality. In trans-esterification, KOH and Methanol are mixed to

create potassium methoxide (K^+ CH_3O). When mixed in with the oil this strong polar bonded chemical breaks the trans-fatty acid into glycerine and ester chains (bio-diesel), along will some soap if you are not careful. The esters become methyl esters. They would be ethyl esters if reacted with ethanol instead of methanol.

Processes In Detail

Pre-treatment (removing of moisture),Trans-esterification,Settling and separation

Pre-Treatment

Oil is first heated to remove moisture content, since waste oil will probably contain moisture, which can slow down the reaction and cause saponification (soap formation). Temperature is raised to 100 degrees to allow any water to boil off.

Figure 1: Pre-Heating

Figure 2: Transesterification Process

Transesterification

During transesterification process the required revolution of the stirrer stirring rpm was to be maintained within the range of 550-700 rpm. It was observed that the required temperature range of water at 60^0C was achieved within 10-15 min and then reaction temperature is remained constant throughout the transesterification process. Increase in process temperature beyond 65^0C will cause formation of vapours of methyl alcohol, because it boils above 70^0C temperature and therefore reaction would be altered. Further increase in the speed of stirring would disturb the process by excessive splashing in the transesterification process. Therefore, the process parameters, such as constant heating at 60^0C and 550-700 rpm were recommended. **Settling and Separation**: Allow the solution to settle and cool for at least eight hours, preferably longer. The methyl esters (bio-diesel) will be floating on top while the denser glycerine will have congealed on the bottom. Then carefully decant the bio-diesel.

Properties of Mahua Oil Methyl Ester

Viscosity	2 cst
Calorific value	38900 kJ/kg
Flash point	75°c
Fire point	78°c
Density	901 kg/m^3

Experimental Test Rig

The setup consists of single cylinder, four stroke, Multi-fuel, research engine connected to Eddy current type dynamometer for loading. The compression ratio can be varied without stopping the engine and without altering the combustion chamber geometry by specially designed tilting cylinder block arrangement. The basic principle of the tilting cylinder block assembly is as shown in Figure. When the CR is to be reduced the block is tilted so that the clearance volume increases and swept volume remains a constant.

Table 3: Engine Specifications

Type	Research engine test set up singlecylinder,4-stroke, VCR engine
Configuration	Naturally aspirated, water cooled, direct injection.
Rated power	3.5 kW @ 1500 rpm
Fuel used	Diesel
Bore	87.5mm
Stroke length	110mm
Compression ratio range	12:1 to 18:1
Dynamometer	Eddy current, water cooled, with loading unit.

Figure 3: Variable Compression Ratio(VCR) Engine Test Rig

Experimental Procedure

Before starting the engine we must ensure that the engine should be in no load condition.

- Check the fuel level, lubrication oil and water, fuel supply of the engine**.**
- Start the engine by self ignition.
- Check the compression ratio of the engine by compression ratio indicator.
- By gradually increasing loads (0 to 12 kgs) at various compression ratios (18-12) note the values of speed, time to consume 10ml of fuel.
- From the above valves we will calculate emission parameters.
- Repeat the steps 5 and 6 with various blends of bio-diesel.

Compression Ratio Adjustment

It is the ratio of total cylinder volume when the piston is at the bottom dead centre to the clearance volume.

The tilting cylinder block arrangement consists of a tilting block with six Allen bolts, a compression ratio adjuster with lock nut and compression ratio indicator. For setting a chosen compression ratio, the Allen bolts are to be slightly loosened. Then, the lock nut on the adjuster is to be loosened and the adjuster is to be rotated to set a chosen compression

ratio by referring to the compression ratio indicator and to be locked using lock nut. The Compression Ratio can be identified by the threads on the Compression Ratio indicator. Finally all the Allen bolts are to be tightened gently. The compression ratios considered for conducting the experiments are 12, 14, 16 and 18.

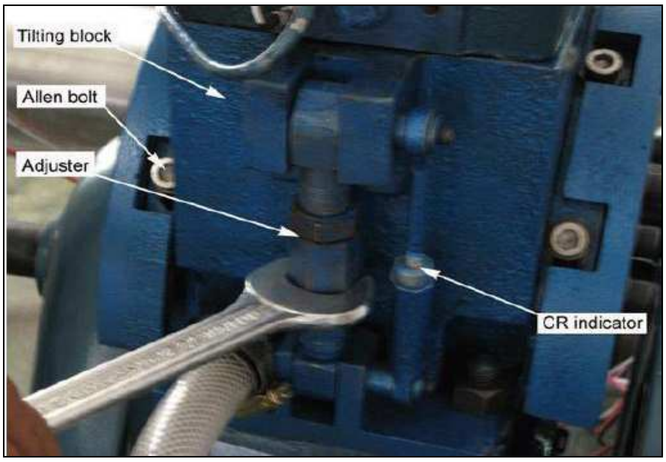

Figure 4: Compression Ratio Adjustment

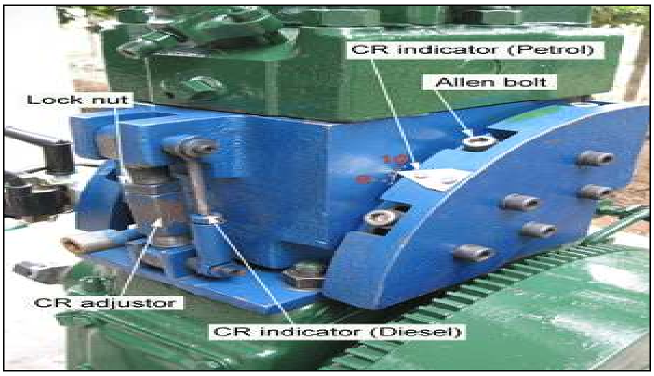

Figure 5: Compression Ratio Indicator

Exhaust Gas Analyzer

Exhaust emissions of an IC engine are unburnt hydrocarbons (HC), oxides of carbon (CO and CO_2), oxides of Nitrogen (NO and NO_2), oxides of Sulphur (SO_2 and SO_3), Particulates, soot and smoke. HC emissions are caused by wall deposit absorption, oil film absorption, crevice volume. CO emission is caused when there is not enough oxygen to convert all carbon to CO_2. NO_x is created mostly from nitrogen in the air. Nitrogen can also be found in the fuel blends. An instrument used to analyze the chemical composition of the exhaust gas released by a reciprocating engine is called exhaust gas analyzer. The instrument measures the concentrations of Carbon monoxide (CO), Carbon Dioxide (CO_2) and Oxygen (O_2) in percentage, Hydrocarbons (HC), Nitric Oxide (NOx) in PPM. The technical specifications of the exhaust gas analyser are given in table 3.1

Technical Specifications of Exhaust Gas Analyzer

Gases Measured	Carbon Monoxide, Hydrocarbons, Carbon dioxide, Oxygen, NOx.
Principle	Non-Dispersive Infrared Sensors for CO, CO_2, HC and Electrochemical sensors for O_2, NOx.
Start-up Time	2 minutes from power ON. Full accuracy in 3 minutes.
Gas Flow Rate	500 – 1000 ml/ min.
Sample Handling System	S.S. Probe, PU Tubing with easily detachable connectors, water separator come filter, disposable particulate fine filter.
Operating conditions	Temperature : 5 to 45˚C,Pressure : 813 to 1060 bar, Humidity: 0-90%

Figure 6: Exhaust Gas Analyzer

When the probe is inserted into the exhaust pipe of the engine the exhaust gas is passed through a metal mesh screen. The screen filters the soot and dust particles after which it is allowed to pass through a fine fibre element which filters the entire gas for any foreign particles. After this, the clean and cool sample gas enters the direct sensor measurement through a filter arrangement and the readings are displayed on the screen and are recorded. Observations mentioned below while conducting the experiment. Various graphs have been plotted between different parameters in order to obtain a comparision between pure diesel and various blends of bio-fuel by varying CR.

RESULTS -TABLE OF READINGS

Table 4: HC Emission AT CR 18

Load(kg)	PD	5BD	10BD	15BD	20BD
0	14	10	11	9	8
3	8	8	7	13	13
6	12	18	28	9	14
9	9	23	28	12	15
12	11	29	23	20	22

Table 5: HC Emission AT CR 16

Load(kg)	PD	5BD	10BD	15BD	20BD
0	22	51	10	46	22
3	20	28	13	25	15
6	13	20	10	17	14
9	11	14	10	13	11
12	9	17	14	25	38

Table 6: HC Emission AT CR 14

Load(kg)	PD	5BD	10BD	15BD	20BD
0	11	105	114	106	30
3	7	71	30	23	18
6	15	33	23	26	29
9	15	17	20	20	31
12	15	38	34	26	39

Table 7: HC Emission AT CR12

Load(kg)	PD	5BD	10BD	15BD	20BD
0	130	313	10	109	167
3	38	120	74	27	96
6	18	30	31	26	53
9	10	28	26	23	40
12	8	48	56	30	47

Table 8: NO_x Emission AT CR 18

Load(kg)	PD	5BD	10BD	15BD	20BD
0	355	460	512	409	409
3	716	716	669	716	716
6	716	673	670	716	716
9	716	716	670	716	716
12	716	666	648	716	716

Table 9: NO_x EmissioN AT CR16

Load(kg)	PD	5BD	10BD	15BD	20BD
0	102	51	95	24	302
3	716	358	409	204	716
6	716	716	669	716	716
9	704	716	670	716	716
12	716	716	669	716	665

Table 10: NO_x Emission AT CR 14

Load(kg)	PD	5BD	10BD	15BD	20BD
0	51	50	51	49	109
3	50	105	102	101	453
6	527	566	669	563	715
9	716	714	670	716	670
12	716	668	670	716	667

Table 10: NO_x Emission AT CR 12

Load(kg)	PD	5BD	10BD	15BD	20BD
0	14	145	112	50	46
3	30	349	102	100	59
6	600	358	667	716	314
9	716	668	669	671	665
12	716	669	671	704	708

5 HC & NOx Emissions Graphs

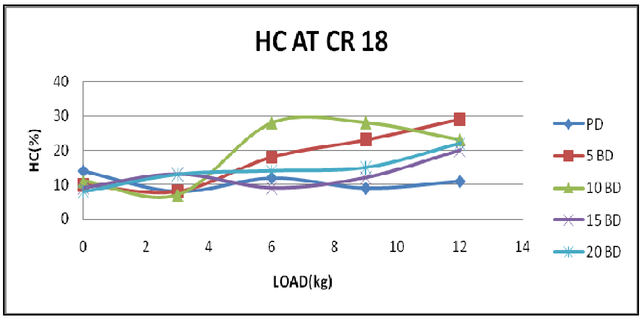

Figure 7

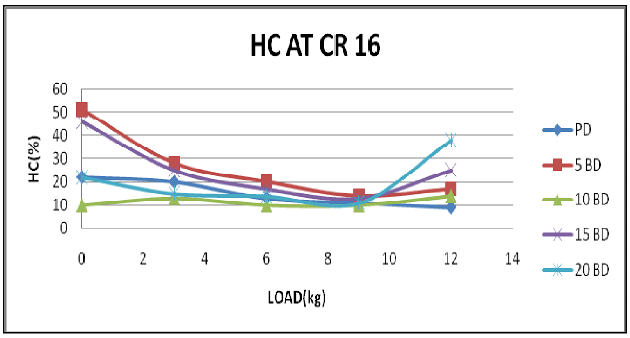

Figure 8

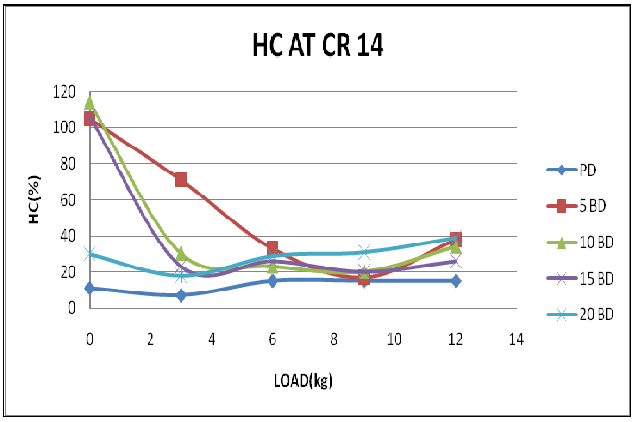

Figure 9

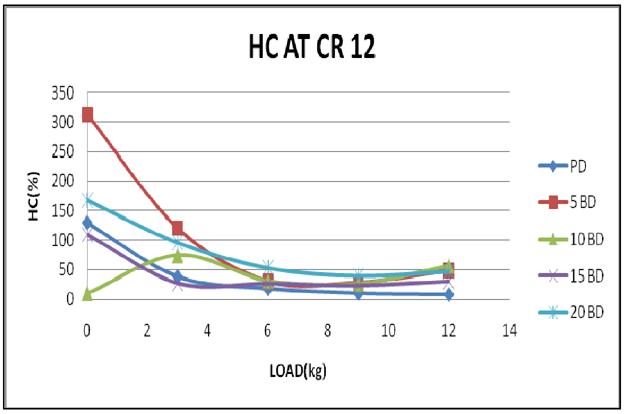

Figure 10

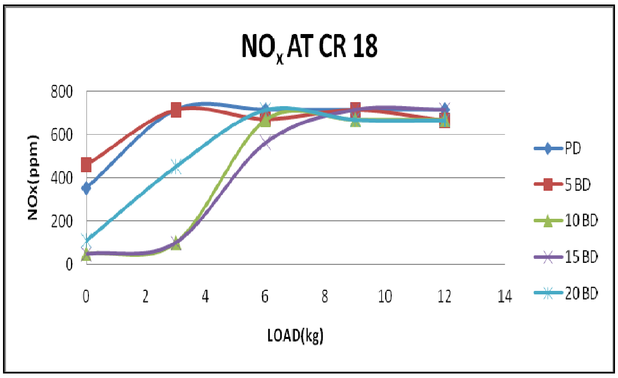

Figure 11

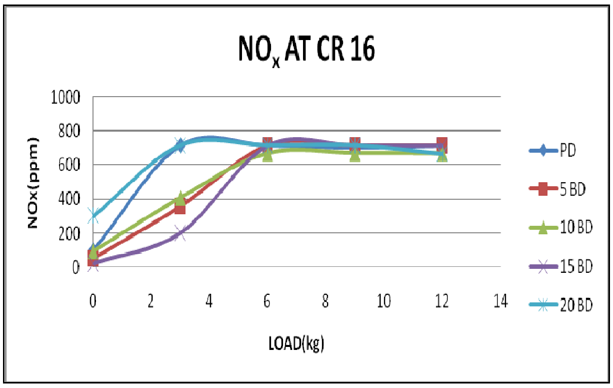

Figure 12

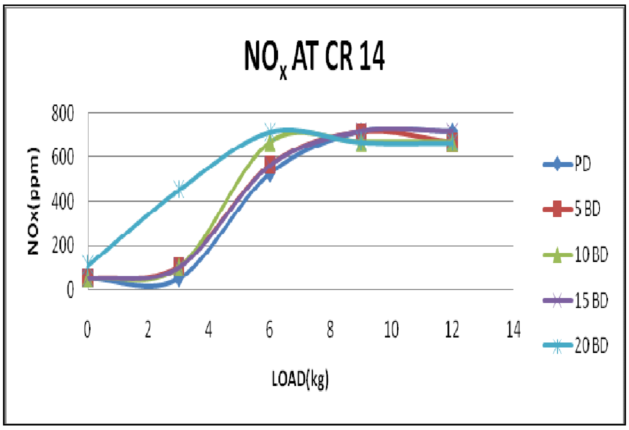

Figure 13

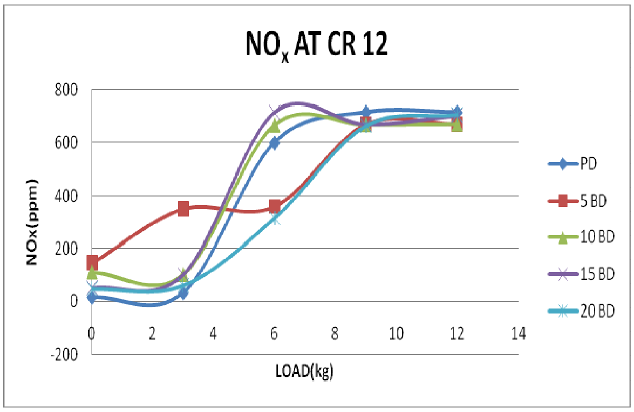

Figure 14

CONCLUSIONS

The study aims to evaluate the suitability of using biodiesel as an alternative fuel in VCR engine. Experimental investigations were carried out on the HC & NOx emission characteristics of the engines. The following conclusions are drawn from the investigations: The HC emissions are 47 ppm at the compression ratio of 12 and 22 ppm at the compression ratio of 18 for maximum load. From the graphs, it is observed that the NOx emissions for esterified Mahua oil is higher with the increase in compression ratio. It is obvious that for higher compression ratio, Nox emissions are higher than that of low compression ratio. The reason for higher NOx emission for easterified Mahua oil is the higher peak temperature. The Nox emission for easterified Mahua oil at the compression ratio of 18 is 716 ppm at maximum load. The HC emissions of the VCR engine slightly decreases as the use of bio-Diese.and as the load and compression ratio increases the emissions. From the above conclusions, it is proved that the biodiesel could be used as an alternative fuel in VCR engine without any engine modifications.

REFRENCES

1. Ramadhas, AS, Jayaraj, S, Muraleedharan, C: Use of vegetable oils as IC engine fuels-a review. Renew. Energy 29, 727–742,2004

2. Lehman, LW, Gauglitz, EJ: The preparation of alkyl esters from highly unsaturated triglycerides. J. Am. Oil Chem. Soc. 40, 197–198,1963

3. Ramesh, A, Nagalingam, B, Gopalakrishnan, KV: Performance of glow plug surface ignition engine with methyl ester of rice bran oil as fuel. In: Proceedings of XI National Conference on IC Engines and Combustion. Indian Institute of Technology, pp. 11–15., Madras, India,1989

4. Panwar, NL, Hemant, Y, Shrirame Rathore, NS, Sudhakar, J: Performance evaluation of a diesel engine fueled with methyl ester of castor seed oil. Appl. Therm. Eng. 30, 245–249,2010

5. Jindal, S, Nandwana, BP, Rathore, N.S, Vashisth, V: Experimental investigation of the effect of compression ratio and injection pressure in a direct injection diesel engine running on jatropha methyl ester. Applied Thermal Engineering. 30, 442–448.2010

6. Monyem, A, Gerpen Van, JH: The effect of biodiesel oxidation on engine performance and emissions. Int. J. Biomass and Bio Energy 20, 317–325,2001

7. Ishikawa, N, Nakada, T: Study of premixed compression ignition on multi cylinder diesel engine. JSAE. 27, 531–538,2006

8. Murata, Y, Kusaka, J, Odaka, M, Daisho, Y, Kawano, D, Suzuki, H: Emissions suppression mechanism of premixed diesel combustion with variable valve timing. Int J Engine Res 8(5), 415–428, 2007.